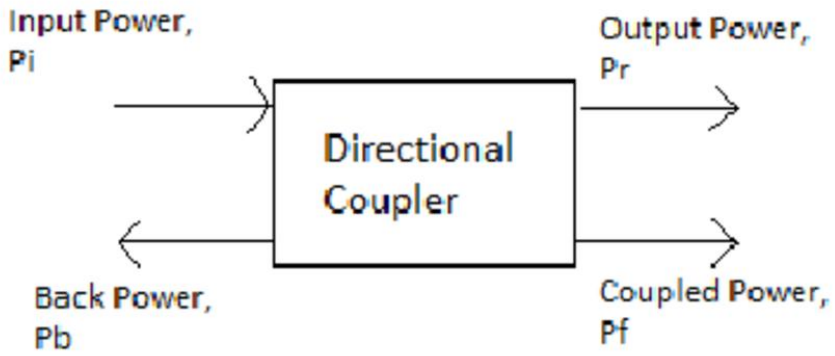
INTRODUCTION TO DIRECTIONAL COUPLERS

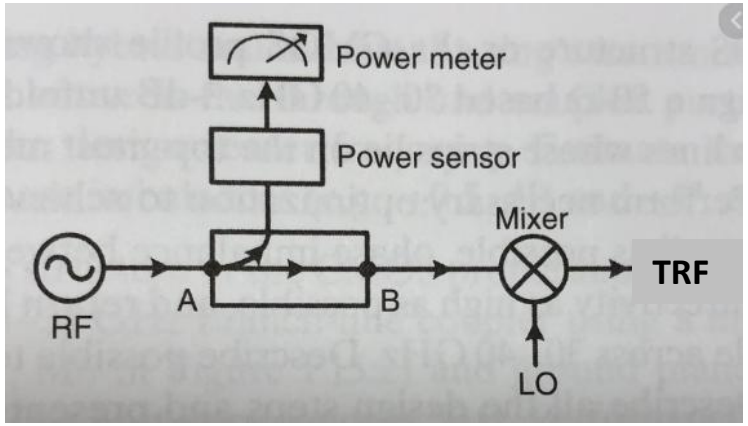
EEEN 566 – MICROWAVE ENGINEERING

Friday, 13 February 2026

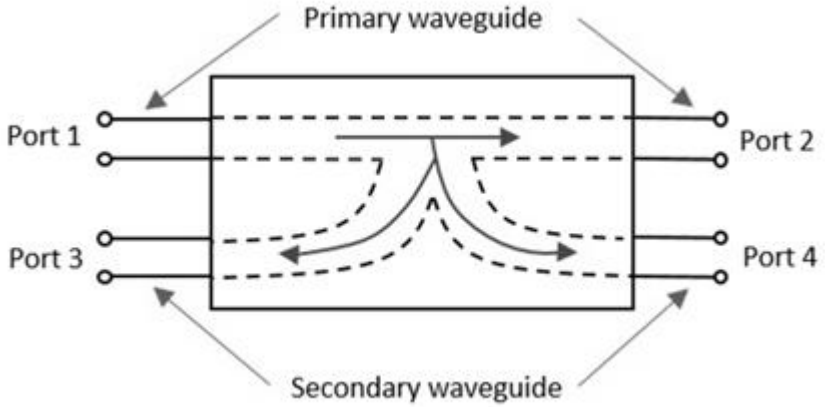
WHAT IS A DIRECTIONAL COUPLER?

1. A Directional coupler is a device that samples a small amount of Microwave power for measurement purposes.
2. The power measurements include incident power, reflected power, VSWR values, etc.



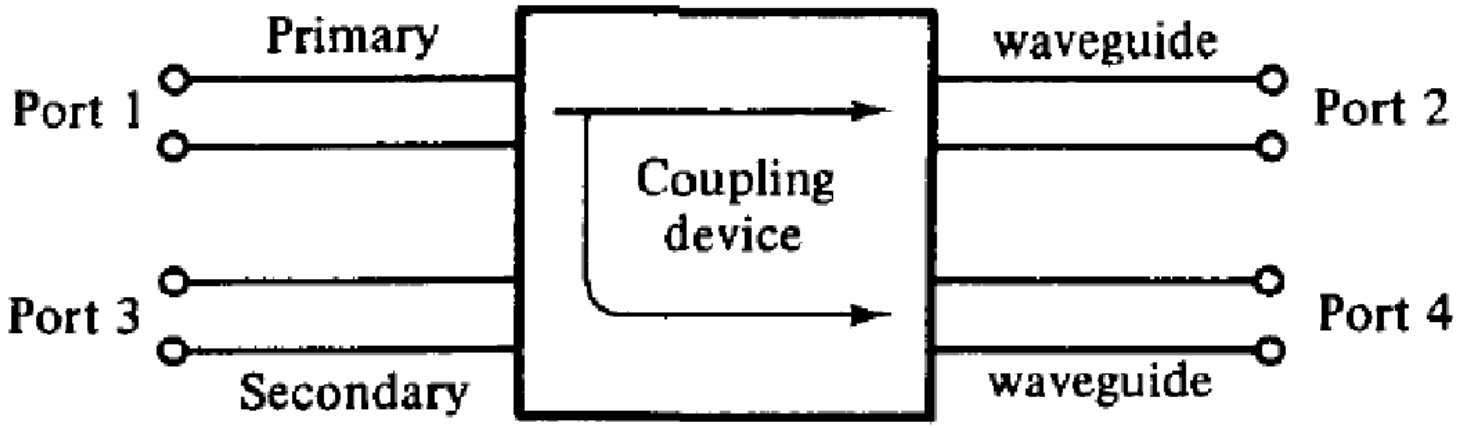


3. Directional Coupler is a 4-port waveguide junction consisting of a primary main waveguide and a secondary auxiliary waveguide.



PORTS OF A DIRECTIONAL COUPLER

- A directional coupler is a four-port waveguide junction consisting of a primary waveguide 1-2 and a secondary waveguide 3-4.



When all ports are terminated in their characteristic impedances,

1. There is transmission of power, without reflection, between port 1 and port 2&4

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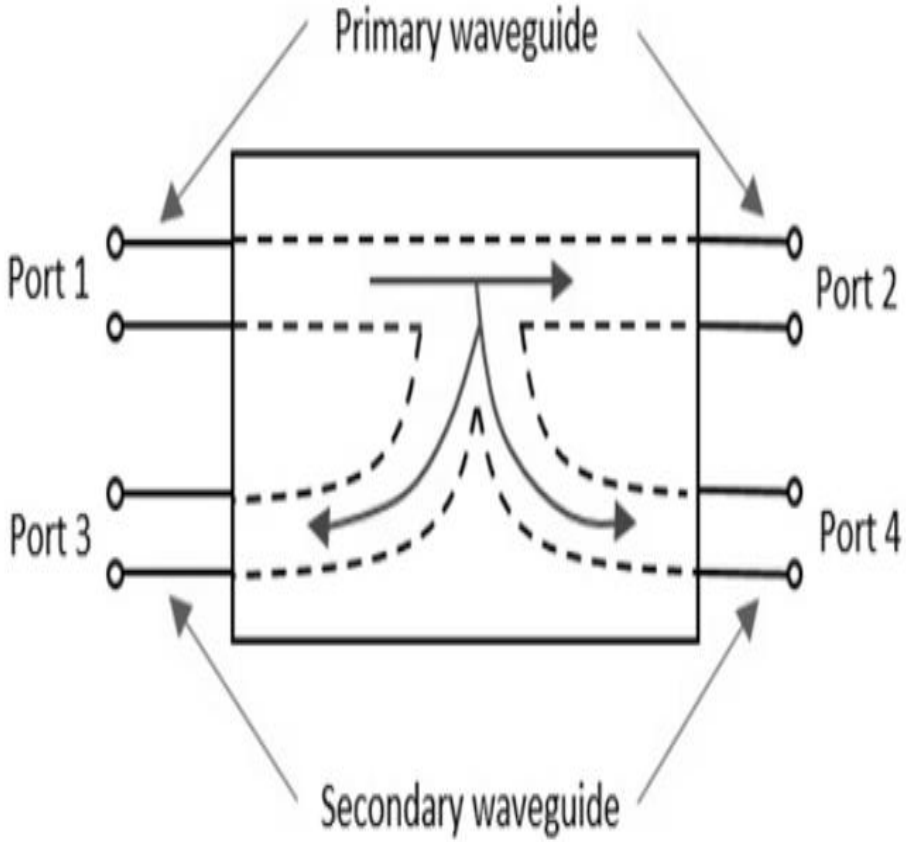
2. There is no transmission of power between port 1 and port 3 and vice versa.

PROPERTIES OF AN IDEAL DIRECTIONAL COUPLER

The properties of an ideal directional coupler are:

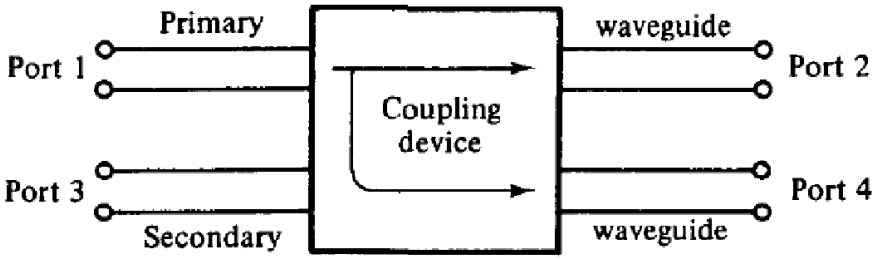
1. All the terminations are matched to the ports.
2. When the power travels from Port 1 to Port 2, some portion of it gets coupled to Port 4 but not to Port 3.
3. Since coupler is bi-directional, when the power travels from Port 2 to Port 1, some portion of it gets coupled to Port 3 but not to Port 4.
4. If the power is incident through Port 3, a portion of it is coupled to Port 2, but not to Port 1.
5. If the power is incident through Port 4, a portion of it is coupled to Port 1, but not to Port 2.
6. Port 1 and 3 are decoupled as are Port 2 and Port 4.



PARAMETERS OF A DIRECTIONAL COUPLER – COUPLING FACTOR

- **The coupling factor** is a measure of the ratio of power levels in the primary and secondary lines.
- Hence if the coupling factor is known, a fraction of power measured at port 4 may be used to determine the power input at port 1.

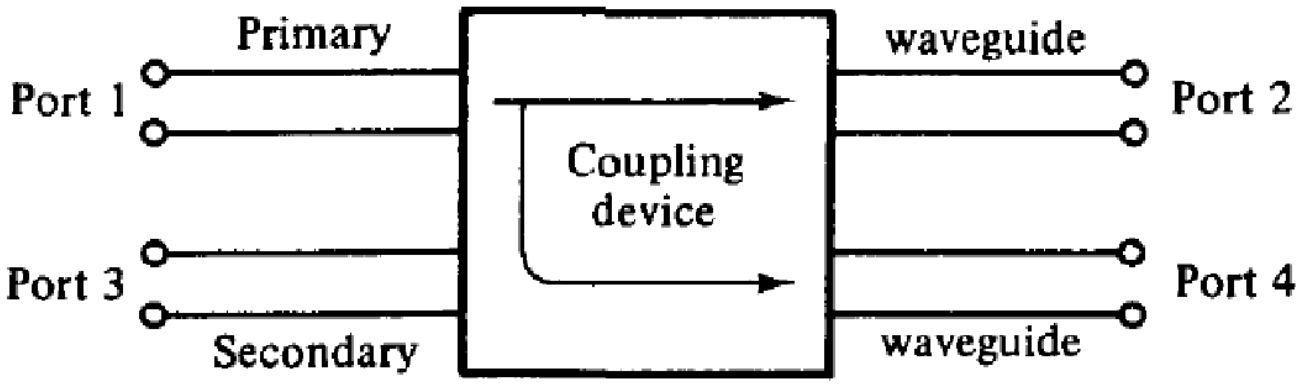
$$\text{Coupling factor (dB)} = 10\log_{10}\left(\frac{P_1}{P_4}\right)$$



PARAMETERS OF A DIRECTIONAL COUPLER – DIRECTIVITY

Directivity of a Coupler is a measure of how well the forward traveling wave in the primary waveguide couples only to a specific port of the secondary waveguide.

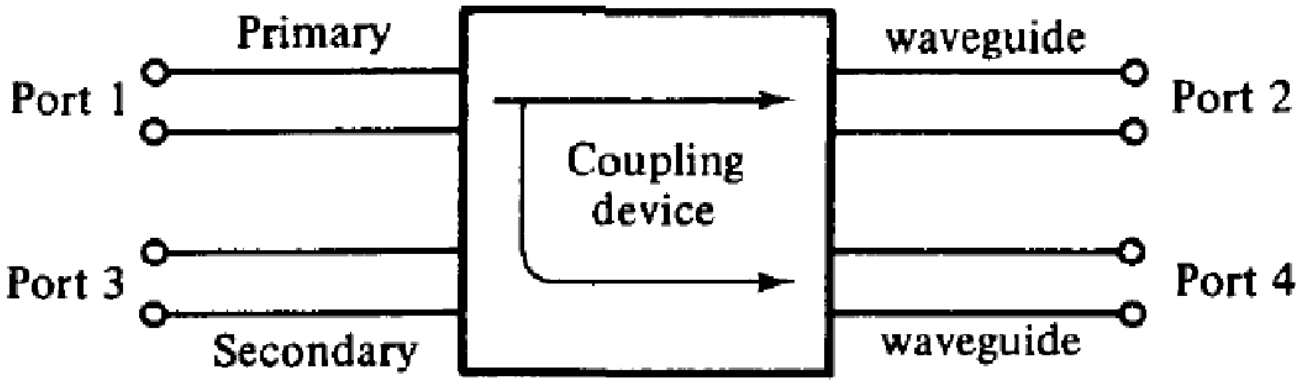
$$\textbf{Directivity (dB)} = 10\log_{10}\left(\frac{P_4}{P_1}\right)$$



PARAMETERS OF A DIRECTIONAL COUPLER – ISOLATION

- **Isolation** defines the directive properties of a directional coupler. It is the ratio of incident power to the back power, measured in dB.

$$\textbf{Isolation (dB)} = 10\log_{10}\left(\frac{P_1}{P_3}\right)$$



Further Reading: [Microwave Engineering - Directional Couplers (tutorialspoint.com)]

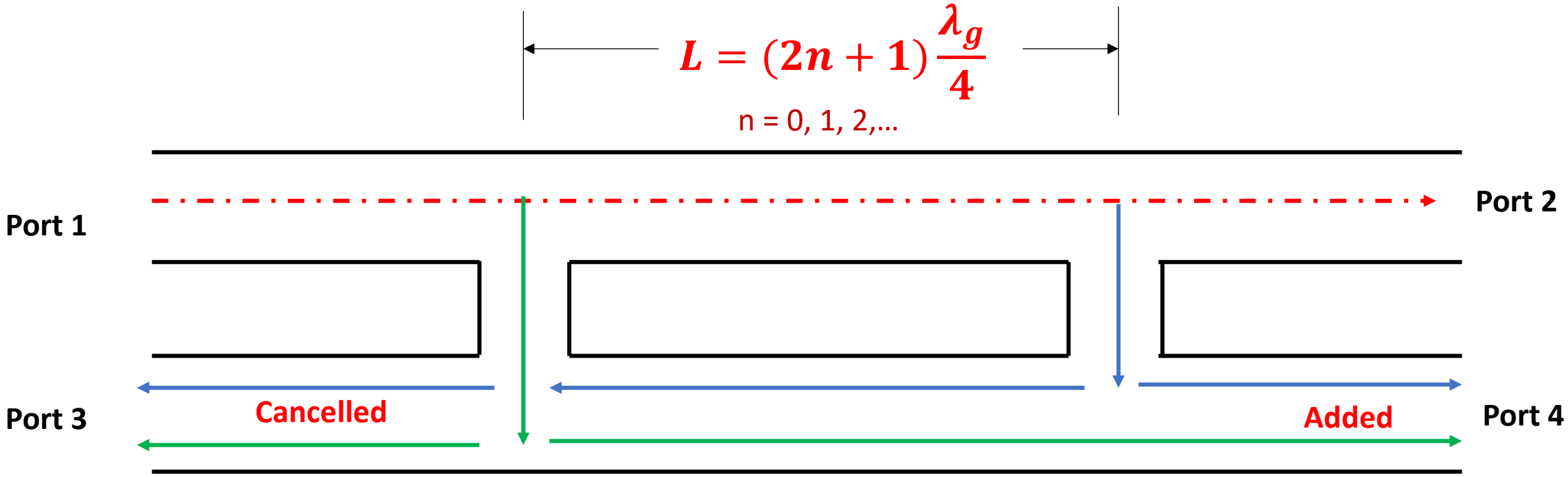
TYPES OF COUPLERS

There are four types of directional couplers, i.e

1. A two-hole directional coupler
2. Four-hole directional coupler
3. Reverse-coupling directional coupler (Schwinger coupler)
4. Bethe-hole directional coupler

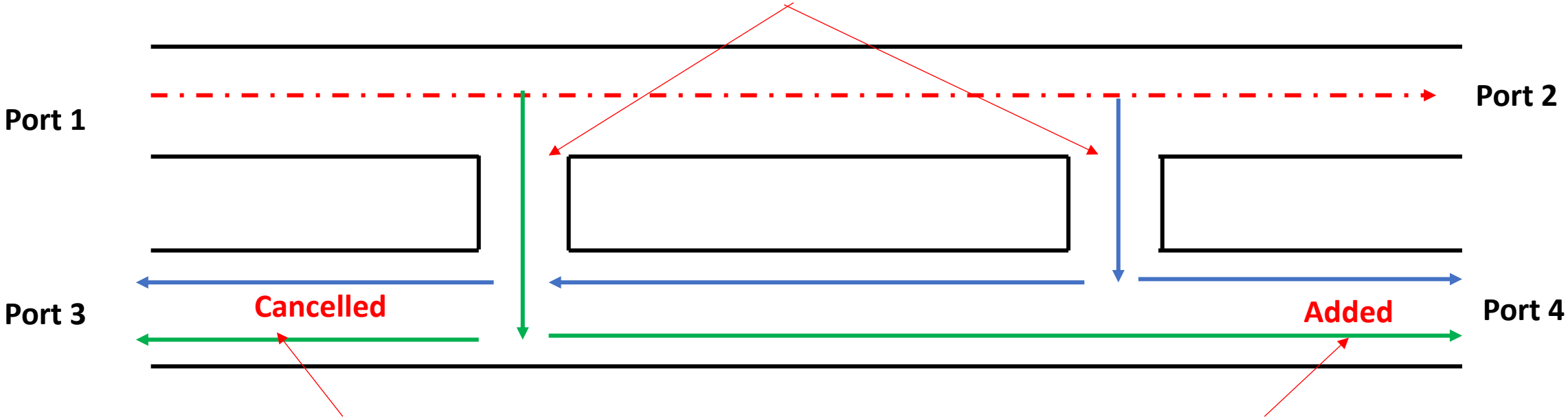
2-HOLE DIRECTIONAL COUPLER (1)

- **Two-hole directional coupler** couples two waveguides using two holes as shown below.



2-HOLE DIRECTIONAL COUPLER (2)

A fraction of the wave energy entered into port 1 passes through the holes and is radiated into the secondary guide as the holes act as slot antennas.

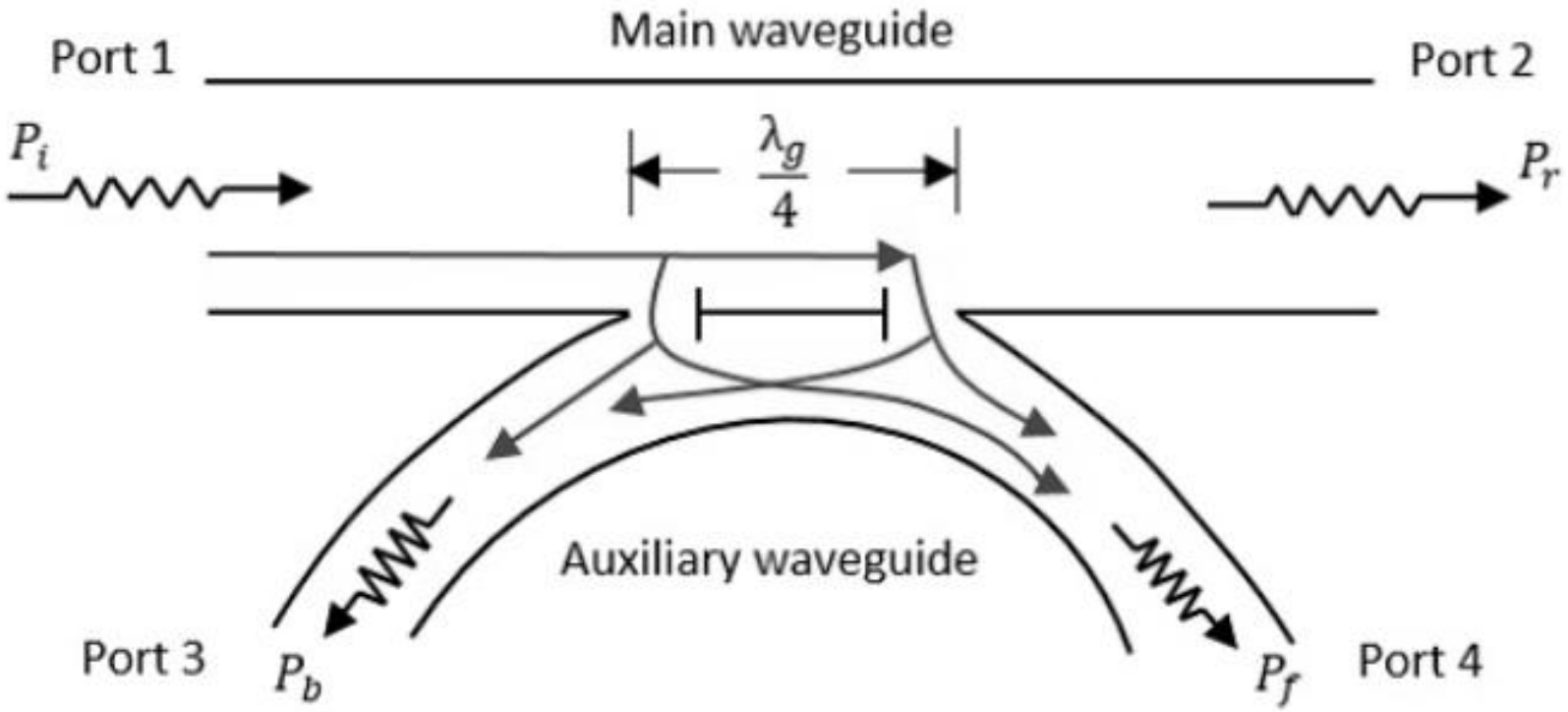


Backward waves in the secondary guide (waves are progressing from right to left) are out of phase and are cancelled at port 3.

The forward waves in the secondary waveguide are in-phase, regardless of the hole size, and are added at port 4.

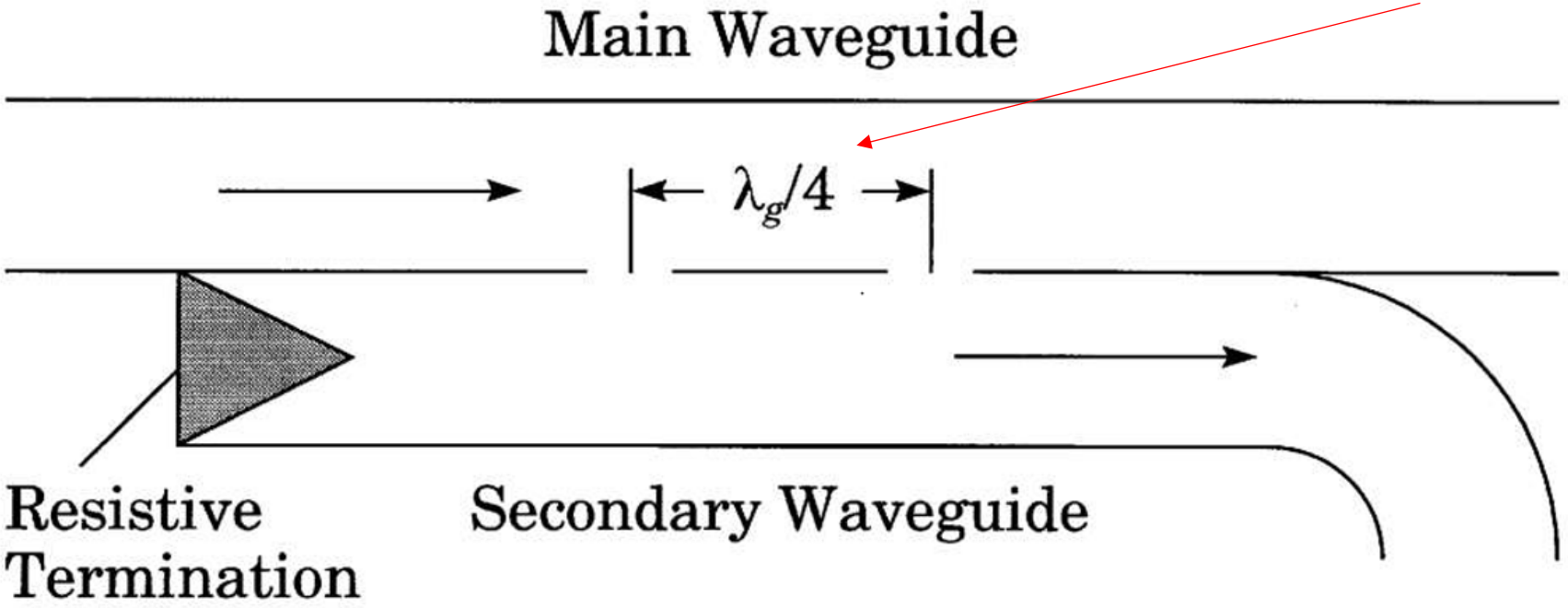
DOMINANT MODE 2-HOLE COUPLER

In practice, most directional couplers operate in the **dominant mode** with main and auxiliary waveguides, but with two small holes that are common between them. These holes are λg/4 distance apart where λg is the guide wavelength.



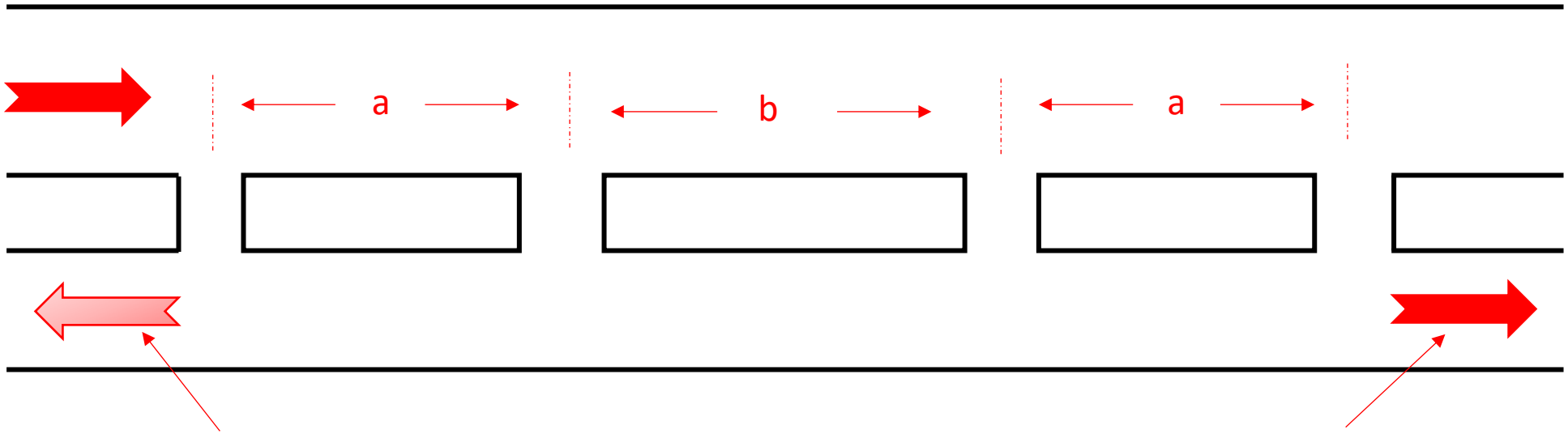
PRACTICAL 2-HOLE COUPLER

$$L = (2n + 1)\frac{\lambda_g}{4}, n = 0$$



In practice, most directional couplers operate in the **dominant mode** with main and auxiliary waveguides, but with two small holes that are common between them. These holes are λg/4 distance apart where λg is the guide wavelength, a resistive termination on port 3.

4-HOLE DIRECTIONAL COUPLER

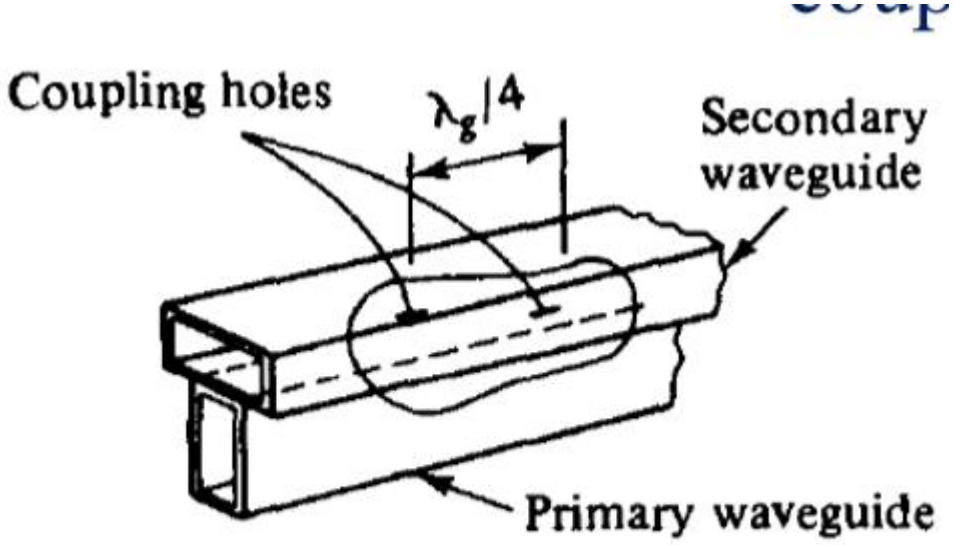


Backward waves in the secondary guide are out of phase and are cancelled at port 3.

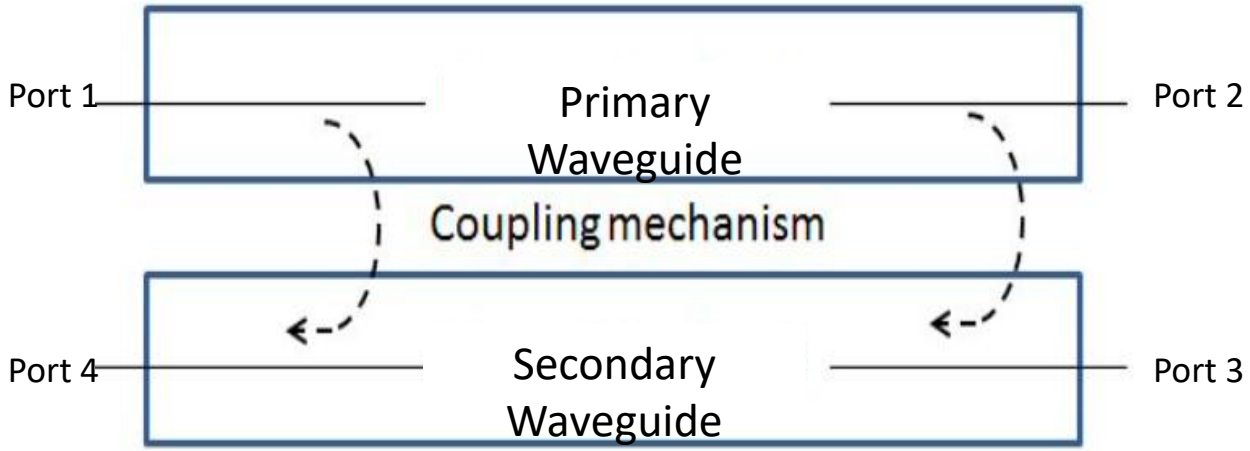
The forward waves in the secondary waveguide are in-phase, regardless of the hole space, and are added at port 4.

SCHWINGER DIRECTIONAL COUPLER

Schwinger directional coupler is a type of directional coupler in microwave engineering, specifically a "reversed-phase coupler" design where the ‘a’ side of one waveguide is shared with the ‘b’ side wall of another, utilizing slots cut between them to achieve coupling.



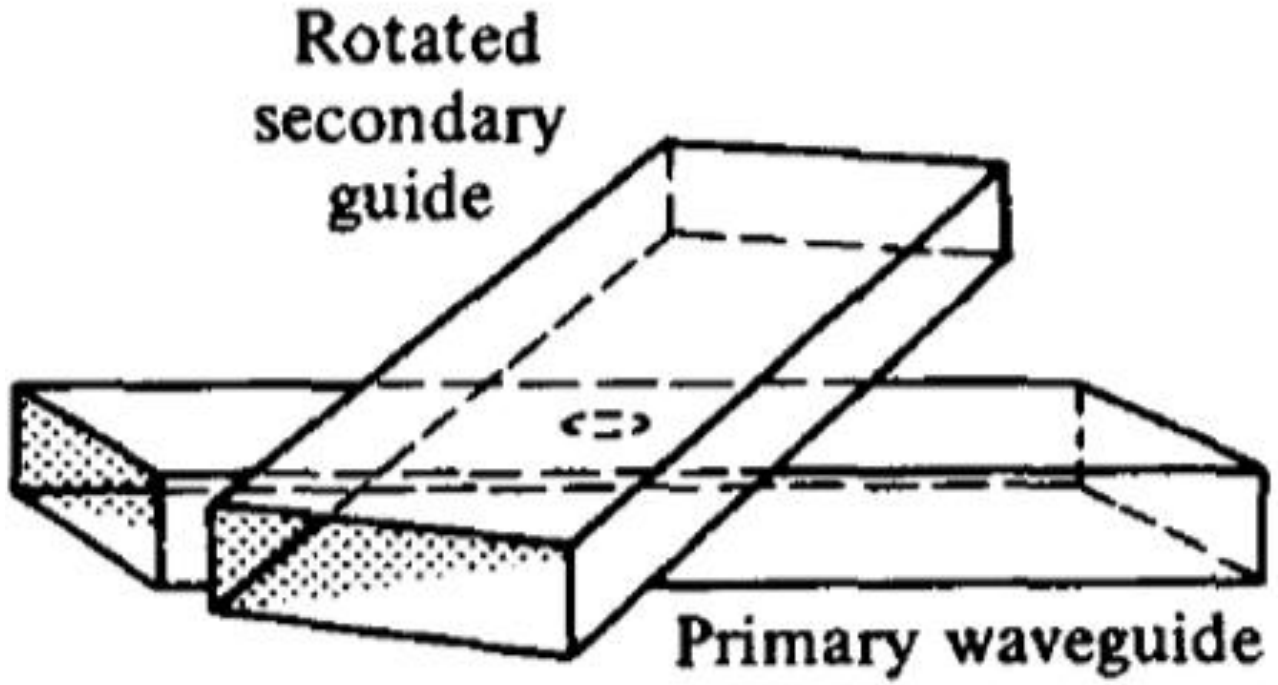
Schwinger coupler



BETHE-HOLE DIRECTIONAL COUPLER

1. **Bethe-hole** is a waveguide directional coupler, using a single hole, and it works over a narrow frequency band.

2. The Bethe-hole is a reverse coupler, as opposed to most waveguide couplers that use multi-hole and are forward couplers.



Bethe-hole directional coupler.

Coupling two waveguides without using a bend.